

## Characterization Sludge from Drying Area and Sludge Drying Bed in Sludge Treatment Plant Surabaya City for Waste to Energy Approach

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### ABSTRACT

The Sludge Treatment Plant (STP) in Surabaya produces solid waste in the form of sludge. The STP in Surabaya provides for Solid Separation Chamber (SSC), equalization unit, Oxidation Ditch (OD), final clarifier, distribution unit, polishing pond, sludge Drying Area (DA), Sludge Drying Bed (SDB), and reservoirs. Sludge waste generation is usually collected in DA and SDB units. This sludge is usually reprocessed for the recycling process, one of which is the waste to energy conversion with a thermochemical process. The difference between these two units is that DA is the sludge from preliminary treatment, while SDB is the sludge from secondary treatment, usually producing microbial biomass. This study aimed to evaluate the sludge produced by the two processing units as solid fuel. The water content of the DA sample is lower because the DA unit has mechanical processing, which separates solids from water. The results of the proximate test resulted in a significant difference between the SDB and DA units. The caloric value, water, ash, and fixed carbon values are significant ( $<0.05$ ), while the volatile values differ for DA and SDB units. This shows that different treatment is needed for each unit to be appropriately processed as fuel.

**Keywords:** sludge treatment, surabaya city, SDB, DA, energy.

### INTRODUCTION

The fecal sludge contains organic loads and high toxicity, impacting the environment and human health (Saleh et al., 2020; Suryawan et al., 2021). In order to achieve the target of Sustainable Development Goals (SDGs), each country is expected to be able to achieve 100% access to sanitation for its population (Hogan et al., 2018; Nhamo et al., 2019; Odagiri et al., 2020). Indonesia put the achievements earlier, namely at the end of 2019 as in the national medium-term development plan (RPJMN). This underlies the need to build a Sludge Treatment Plant in Surabaya as an integrated effort to overcome and prevent the existing problems. However, increasing sludge

disposal practices are due to two factors, namely technical and non-technical factors. The technological factors include variable inflow, short detention time, and the effluent quality that does not meet the criteria waste quality standards. In addition, excess nutrient compounds will trigger algae growth, which will cause pollution in water bodies (Afifah et al., 2020; Prajati et al., 2021; Septiariva & Suryawan, 2021). According to PUPR Ministerial Regulation Number 4 of 2017, the sludge formed in the local treatment unit like a septic tank still requires further processing in STP (Permen PUPR, 2017). STP is a facility that functions to receive and treat fecal sludge transported by excreta trucks, one of which is the Surabaya STP. The Surabaya STP has nine treatment units,

consisting of a Solid Separation Chamber, an equalization unit, oxidation ditch unit, final clarifier, distribution unit, polishing pond, Sludge Drying Bed (SDB), sludge Drying Area and reservoir.

Every year, the population growth will be in line with the continued increase in fecal sludge production (Berendes et al., 2018; Koko et al., 2022). On the basis of the research by Milis (2014) conducted in several cities in Indonesia, the accumulation of fecal sludge formed at the local processing unit is 13–130 L/person/year. This shows that with a large population of Surabaya, the amount of sludge production will continue to increase and has the potential to be utilized. Excess fecal sludge is considered an unwanted by-product in wastewater treatment facilities, as it requires special handling due to its significant volume (excess sludge) and organic and pathogenic content. On the basis of the STP data in 2020, the discharge that enters the STP is 110–115 m<sup>3</sup>/day and produces approximately 27 m<sup>3</sup>/day sludge. Therefore, the dry sludge produced by the Surabaya STP can be used as an alternative fuel. The residual process sludge has a calorific value of 3000 kcal/kg (Dong & Lee, 2009), and as for the characteristics of the feces from the SDB unit, it has a calorific value of 4168 cal/gram which means it has the potential to be used as refuse derived fuel (RDF) (Rizkiyah & Yudihanto, 2013). The purpose of this study was to determine the potential utilization of fecal sludge from the Surabaya STP to be used as raw material for RDF.

## METHOD

The research was conducted at the Surabaya STP (Figure 1), in Sukolilo District, in Surabaya City, East Java Province. The initial step of the research begins with the formulation of the problem, then proceeds with the collection of primary and secondary data. First, primary data collection was carried out at the Surabaya STP. There are two types of samples to be taken, namely wet sludge samples and dry sludge samples, each coming from two sources, namely SDB and DA. The primary data used in this study is the data related to the sludge characteristics from the Surabaya STP. Determination of pollutant load capacity, based on Ministry of Environment Decree No. 110 of 2003, can be performed using the formula in Equation (1).



**Figure 1.** Satellite Image of Keputih Surabaya STP (Google Map, 2021)

$$C_R = \frac{\sum C_i Q_i}{\sum Q_i} = \frac{\sum M_i}{\sum Q_i} \quad (1)$$

where:  $C_R$  - Average concentration of constituents for combined flow,  $C_i$  - Concentration of components in the  $i$ -th stream,  $Q_i$  -  $i$ -th flow rate,  $M_i$  - Constituent Period in the  $i$ -th stream.

The sludge characteristics will be known through direct observation and laboratory tests with several parameters, including water content, volatile matter, ash content, fix carbon, and calorific value. The dry samples from the Surabaya STP from two sources, namely DA and SDB, will be the raw material for RDF. The proximate test was carried out with the ASTM D3172 - ASTM D3175 standard, while the calorific value test was carried out with ASTM D-5865-04. The secondary data needed will be obtained from the relevant parties or government agencies that handle the White STP Surabaya City from the Surabaya STP data or reports. The data required are the data on the flow of sludge entering the Surabaya STP, the age of the sludge in the related units, namely DA and SDB, the mass balance of the sludge from the Surabaya STP processing. In this study, two variables were used, i.e. DA and SDB. The analysis used to see the difference in the quality of sludge in DA and SDB uses analysis of variance (ANOVA). The purpose of ANOVA is to find the independent variables in this study, namely calorific value, water, ash, and fixed carbon values

are significant water content, volatile matter, ash content, fixed carbon grouped by DA and SBD as well as to determine the interaction between these variables and their effect. The use of ANOVA is based on the assumption that the data are normally distributed, the variance is homogeneous, the sampling is random, and each sample is independent. One way ANOVA is a one-way analysis of variance which is a procedure to test the average or treatment effect of several populations (more than two) from an experiment that uses one factor, where one factor has two or more levels.

## RESULTS AND DISCUSSION

The sanitation vision of Surabaya is to provide reliable, efficient, and environmentally friendly sanitation services for the people of the City of Surabaya by delivering an appropriate sanitation system for the disposal of domestic waste. One of the sanitation systems implemented in Surabaya is a centralized sanitation system located in the Keputih Village, Sukolilo District. The centralized sanitation facility is the Surabaya STP, a sludge treatment facility in Surabaya operating since 1991. The STP, which is in East Surabaya, has an area of about 3.1 hectares with a storage capacity of 400 m<sup>3</sup>/day.

The Surabaya STP is one of the UPTD (Technical Implementing Units) under the Surabaya City Cleanliness and Green Open Space (DKRTH) Office. In the Surabaya STP, only fecal waste is processed and used as planting media or fertilizer. All units in the Surabaya STP are still functioning well to treat sewage, with a minimum of 30 cycles for the transport fleet carrying an average of 100 m<sup>3</sup>/day of sewage. The wastewater treatment process at the Surabaya STP can be seen in Figure 2. The sludge from the sewage trucks is dumped into the SSC, which has a bar

screen installed at the beginning of the unit. The bar screen aims to filter out large particles, which float on the fecal sludge before entering the SSC. Furthermore, the fecal sludge undergoes a filtering process by sand and gravel, so that there is a separation of solids and liquids, and the solids are above the SSC sand layer. After a few days, the crane lifts it to a dump truck to be dumped into the DA unit. The cake in the DA undergoes a dewatering process with the help of sunlight and produces dry solid.

The filtrate from the SSC and SDB units, accommodated in the sump well, is also pumped as diluent water in the OD unit. The supernatant undergoes an aerobic biological process with a mammoth rotor for aerated sludge, and an anoxic process occurs through the flow of fecal sludge surrounding the OD. In the FC, the supernatant undergoes a precipitation process from the biological floc (Asensi et al., 2019), so there is a separation between the biological floc and the clean water. The sludge that flows into the SDB unit undergoes a filtration process by sand and gravel to separate solids and liquids. The water passes through the filter layer and enter through the underdrain pipe at the bottom of the SDB to the sump well unit by gravity. In turn, the solids on the sand undergo a dewatering process with the help of sunlight, dry soil is produced, which is taken by officers to be used as plant fertilizer. The cake from the SDB is taken and transported to the DA unit if the SDB capacity is no longer available. DA is different from SDB, because there is no filter layer on DA. The following explains the number, dimensions, and each processing in the Surabaya STP, shown in Table 1. The Surabaya STP receives the sewage sludge from a privately owned stool transporting truck. The processed sewage sludge is calculated based on the number of incoming transport fleets with a capacity of 3.7–5.6 m<sup>3</sup> and an average of one cycle per

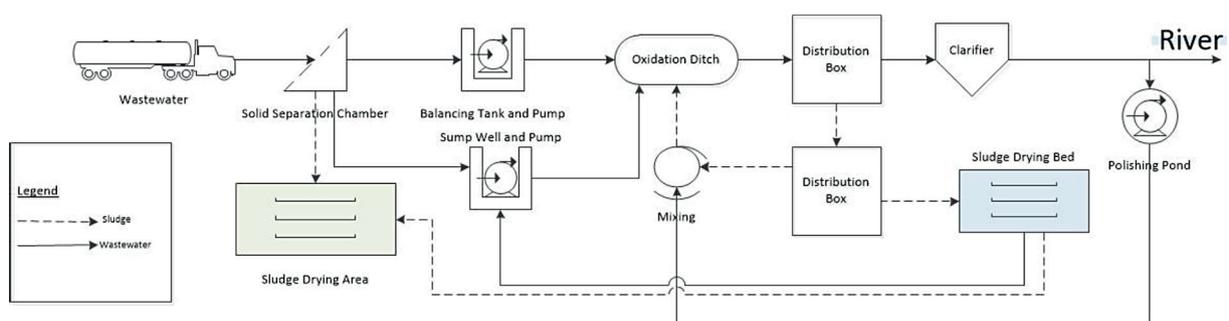


Figure 2. Flowchart of Surabaya STP processing

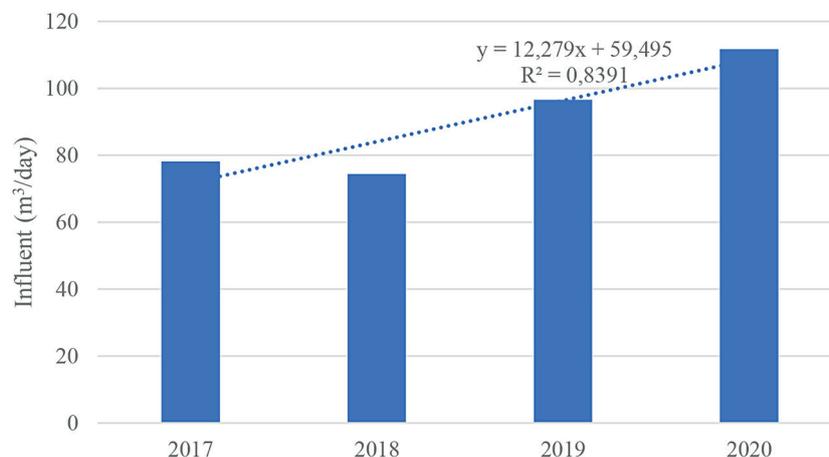
**Table 1.** Number, dimension, and function of each processing unit

Unit	Total unit	Dimension	Functional
Solid Separation Chamber (SSC)	4	18 × 8 × 2.75	Separates solids with water mixed with fecal sludge.
Balancing Tank (BT)	2	18 × 6 × 2.5	Homogenize organic and hydraulic loads of wastewater.
Oxidation Ditch (OD)	4	60.2 × 4 × 1.85	Removing organic matter contained in wastewater by utilizing microorganisms.
Final Clarifier (FC)	2	6 × 2.45 × 1.85	Separate water and solids to optimally treat water in the polishing pond unit.
Polishing Pond (PP)	1	15.4 × 6.1 × 2.5	Remove nutrients in nitrogen and phosphorus to produce a more hygienic effluent.
Sludge Drying Bed (SDB)	24	34 × 25 × 0.9	Area for the sludge drying process from the clarifier unit with a natural process using sun drying and return sludge.
Drying Area (DA)	2	34 × 25 × 6.9	Area for the sludge drying process from the Solid Separation Chamber (SSC) unit with a natural process using sun drying.

day. The average amount of sludge that enters the STP is 100 m<sup>3</sup>/day in the dry season and 150 m<sup>3</sup>/day in the rainy season. The capacity used by the Surabaya STP is 37.5%. However, the operating system is optimal (Putri & Hermana, 2015). The following average influent data for the Surabaya STP sludge treatment from 2017–2020, as shown in Figure 3. The sludge produced by the STP is the sludge from physical treatment in the drying area and biological treatment in SDB. From the STP data for 2017–2020, the highest average discharge in 2020 is 111.71 m<sup>3</sup>/day. On the basis of the known influent data, it can be estimated that sludge is produced every day. The sludge density is known to be 1.020–1.030 kg/m<sup>3</sup> (Andreoli & Fernandes, 2007). The known volume data will be converted into mass data to determine the daily sludge production in Figure 4.

The DA unit assists in drying the sludge after it is removed from the solid separation chamber

unit through natural evaporation by sunlight. In turn, the SDB Unit functions to help the process of drying sludge from the final clarifier unit by natural evaporation by sunlight. These two plants have sludge loads for DA and SDB of 17.81 and 8.94 m<sup>3</sup>/d, respectively (Table 2). Determination of the level of need for STP in an area depends on the conditions that cause drainage services. The characteristics of sewage sludge to determine the content of organic load serve as a basis for consideration to determine the necessary further treatment (Callegari & Capodaglio, 2018; Wang et al., 2019; Wu et al., 2020). Evaluation of the carrying capacity of sewage treatment system pollutant loads is calculated using the mass balance method (Ruan et al., 2019). The mass balance method determines the concentration of the mixture between wastewater and the pollutant source. The calculation formula can be seen in equation (1), and

**Figure 3.** Influent data for sludge treatment in Surabaya STP

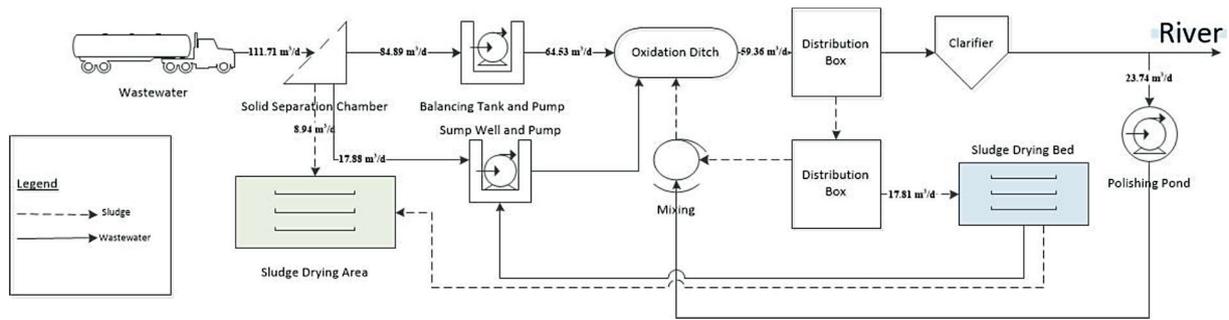


Figure 4. Mass balance sludge flowrate of Surabaya STP

Table 2. Mass balance sludge flowrate of Surabaya STP

Parameters	Treatment process	% Load	Sludge rate (m³/day)
Influent load	-	100%	111.71
Sludge load	Solid Separation Chamber (SSC)	100%	111.71
	Balancing Tank (BT)	76%	84.89
	Oxidation Ditch (OD)	76%	64.53
	Final Clarifier (FC)	92%	59.36
	Sludge Drying Bed (SDB)	31%	17.81
	Drying Area (DA)	8%	8.94
Sludge production	SDB + DA	0.39	26.75

the complete pollution load in Surabaya STP can be seen in Table 3. The nutrient load in the form of nitrogen (N) and phosphate (P) is still present at the end of processing, although it is lower than the organic and solid load. The impact of this nutrient needs to be further utilized (Afifah et al., 2020; Sarwono et al., 2022) to avoid deteriorating water conditions in Surabaya. The wet sludge characteristics were obtained through laboratory testing. The characteristics of the wet sludge were measured by calorific value and proximate parameters. Wet sludge samples were taken from the DA and SDB units. To determine the initial characteristics of the sludge, fresh sludge samples were used. The results of testing the initial characteristics of wet sludge with calorific value and proximate parameters can be seen in Table 4.

This study shows that the calorific value, water, ash, and fixed carbon values are significantly different ( $\text{sig} < 0.05$ ) between the sludge in the DA and SDB units. Meanwhile, the values of volatile levels in DA and SDB are the same ( $\text{sig} > 0.05$ ) (Table 5). The calorific value produced from the SDB sludge sample is greater than the DA sludge sample. This is because the sludge produced from the SDB unit has undergone biological treatment. The calorific value produced is higher than the sludge from the DA unit, which only goes through mechanical processing, namely the separation between solids and water. In addition, the pollutant produced is in organic matter, most of which is converted into methane gas, resulting in a reasonably high calorific value (Rasheed et al., 2021). Proximate testing consists of several parameters. It can be seen in

Table 3. Mass balance pollution load of Surabaya STP (Dian & Herumurti, 2016)

Parameters	Influent		Solid Separation Chamber (SSC)		Oxidation Ditch (OD)		Final Clarifier (FC)	
	Concentration (mg/L) <sup>1</sup>	Load (kg/day)	% Removal <sup>1</sup>	Load (kg/day)	% Removal <sup>1</sup>	Load (kg/day)	% Removal <sup>1</sup>	Load (kg/day)
TSS	8320	74478.6	44.41	41402.6	98.27	716.3	0	716.3
BOD	792.53	7094.5	19.71	5696.2	87.72	699.5	0	699.5
COD	1600	14322.8	20	11458.2	87.5	1432.3	0	1432.3
N	617.8	5530.4	0	5530.4	99.03	53.6	29.83	37.6
P	185.22	1658.0	0	1658.0	84.77	252.5	59.8	101.5

**Table 4.** Differences between sludge quality in DA and SDB

Parameters	Unit	Drying area (DA)					Sludge drying bed (SDB)				
		1	2	3	4	5	1	2	3	4	5
Caloric value	cal/g	3935	3865	3751	3814	3892	4169	4049	4103	3949	4140
Water content	%	24.62	26.31	27.21	26.91	26.39	30.25	30.21	30.41	29.08	30.9
Volatile matter	%	45.77	44.29	44.57	44.67	50.58	46.45	47.29	44.98	48.45	48.76
Ash content	%	28.68	28.42	27.31	27.49	22.14	23.12	22.32	24.42	22.31	20.13
Fix carbon	%	0.93	0.98	0.91	0.93	0.89	0.18	0.18	0.19	0.16	0.21

**Table 5.** ANOVA test results differences parameters in Sludge Quality DA and SDB

Parameters		Sum of squares	df	Mean square	F	Sig.
Caloric value	Between groups	132940.9	1	132940.9	21.079	0.002
	Within groups	50453.2	8	6306.65		
	Total	183394.1	9			
Water	Between groups	37.675	1	37.675	51.816	0
	Within groups	5.817	8	0.727		
	Total	43.491	9			
Volatile	Between groups	3.66	1	3.66	0.786	0.401
	Within groups	37.258	8	4.657		
	Total	40.919	9			
Ash	Between groups	47.263	1	47.263	9.857	0.014
	Within groups	38.358	8	4.795		
	Total	85.621	9			
Fix carbon	Between groups	1.384	1	1.384	1908.745	0
	Within groups	0.006	8	0.001		
	Total	1.39	9			

the table of parameters pertaining to the water content of the SDB sludge sample, which has a value of 30.25%. This value is higher than the water content of the DA sample of 24.62%. The water content of the DA sample is lower because the DA unit has mechanical processing, which separates solids from water. From the test results of the two samples, it can be concluded that the water content contained in the material is still high enough so that a dewatering or drying process is needed. The ash content parameter indicates the residue remaining after burning the fuel (Dinesha et al., 2019; Suryawan et al., 2022). The ash content of the fuel is inversely proportional to the calorific value of the energy. The lower the ash content in the fuel, the higher the value produced and vice versa (Sukarta & Ayuni, 2016). The DA sample had a higher ash content than the SDB sample. This parameter indicates that the higher the volatile matter content, the greater the heating value released as combustion vapor (Oberberger & Thek, 2004). The test results showed that the SDB sample had

a higher volatile content than the DA sample. Theoretically, if the volatile content of the waste is high (inversely proportional to the ash content) and the calorific value of the waste reaches a minimum of 1500 cal/gr, then the waste can be burned in an incinerator (Allen & Abarca, 2021). This high value is most likely due to most of the solid waste composition in the form of dry waste with a small amount of water content.

Finally, fixed carbon is a parameter that indicates the remaining carbon after the volatile matter is released in the combustion process (Seri et al., 2020). The tethered carbon content of the DA sample was 0.93%. In contrast, the tethered carbon content of the SDB sample was lower at 0.18%.

## CONCLUSIONS

The Keputih Surabaya STP processing sludge comes from physical processing, namely from the Drying Area unit and biological processing from the Sludge Drying Bed unit. The

calorific value of the 5-day-old Drying Area sludge is 3,935 cal/gr. At the same time, the 3-day-old Sludge Dring Bed is 4,169 cal/gr. On the basis of the standard calorific value set by the Ministry of Industry. The Surabaya Surabaya STP processing sludge can be used as raw material by a drying process to obtain the water content according to the standard.

## Acknowledgments

This research was supported by the collaboration Universitas Pertamina (UP) and Universiti Teknologi PETRONAS (UTP) [Grant Number 0540/UP-WR3.1/PJN/bIX/2020].

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